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HAZARDS ANALYSIS OF ENERGY RECOVERY FROM ARMY AMMUNITION PLANT SOLID WASTE

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APRIL 1979

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The generation of large quantities of solid waste at Army Ammunition Plants provides a potential fuel source to reduce dependence on costly fossil fuels. The current methods of disposing of this waste don't take advantage of the 15.7 MJ/kg heat content of the waste. The report discusses the potentially hazardous conditions of processing this waste for use as a fuel.

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TABLE OF CONTENTS

	Page No.
Introduction	1
Discussion	3
Process Description	3
Processing Hazards	7
Conclusions	13
Recommendation	13
References	14
Bibliography	14
Appendix A - Propellant and Explosive Sensitivity Data	17
Distribution List	25
Tables	
1 Explosions in grinders	2
2 Pyrolysis processes	4
Figures	
1 Typical pyrolysis process.	6
2 Fault tree analysis of grinding process.	11

INTRODUCTION

The generation of large quantities of solid waste at Army Ammunition Plants (AAP's) provides a potential fuel source to reduce dependence on costly fuels. In the manufacture, loading, assembly, and packing of munition items, there are various non-usable wastes generated which must be disposed of in a safe and ecologically sound manner. This disposal has come under close scrutiny due to the EPA's regulations (state and federal) and the revocation of Part 76 of Title 40, CFR on March 25, 1975 which rescinded a federal exemption on open burning of these wastes. Open burning is characterized by stockpiling of hazardous materials (waste propellants and explosives), air and water pollution, personnel exposure, and inefficient combustion.

In order to eliminate these problems and take advantage of the 15.7 MJ/kg (7,000 BTU/lb) heat content of the wastes, two energy recovery processes currently being used with municipal solid waste and other types of biomass are being considered. One process converts the solid waste into refuse derived fuel (RDF). The second process involves converting the waste by pyrolysis to either a liquid, a solid, or a gaseous fuel product. The resultant fuels can be used by themselves or in combination with fossil fuels. Due to the explosive nature of P&E wastes, special considerations must be given to the potential hazards in each process.

The probability of the presence of a significant quantity of explosive material in the waste (exceeding the critical depth) and the potential for detonation and injury have been sufficiently high to preclude the consideration of AAP waste as a potential fuel source. However, this situation is not unique to the Army, since quantities of commercial and military explosives are finding their way into municipal solid waste (table 1). In several cases investigators discovered the origins of incinerator blasts were not sabotage, but merely the result of explosives being added to the solid waste by chance. For example, some ammunition that had become wet was thrown away by hunters and ended up in the municipal waste. In another incident, a "mad bomber" got cold feet and discarded his bomb in a trash container. War souvenirs and compressed gas cylinders account for a large amount of this hazardous litter. Consequently, it is obvious that the processing of AAP solid waste has a lot in common with the processing of municipal waste.

Table 1. Explosions in grinders

DCOUMENTED EXPLOSIONS IN DIFFERENT TYPES OF GRINDERS (SHREDDERS)(ref. 1)

Shredder type	Number of locations	Number of shredders	Number of explosions
Vertical grinder	8	11	24
Horizontal hammer mill	24	38	47
Vertical hammer mill	15	17	24
Total	47	66	95

MATERIALS RESPONSIBLE FOR GRINDER EXPLOSIONS

	Flammable vapors & gases	Commercial or military explosives	Undetermined	Total
No. of Explosions	30	11	54	95

The scope of this report is limited to those hazards which are peculiar to the processing of explosive waste. It does not deal with more conventional safety considerations (i.e., slipping, safety clothing, and/or guards) which are covered in the OSHA regulations.

DISCUSSION

Process Description

There are two processes that can be used to recover energy from AAP solid waste - refuse derived fuel (RDF) and pyrolysis. The refuse derived fuel involves processing the solid waste, recovering the light combustible fraction of the refuse, and refining it into a viable fuel source. RDF can be combusted in utility boilers either as the primary fuel or in conjunction with fossil fuels. The higher heating value (HHV) of refuse derived fuel is 15.7 MJ/kg compared to about 23.2 MJ/kg for coal. RDF is produced by the grinding and/or chemical treatment of solid waste. The solid waste is sent to the primary shredder (usually a flail mill) where initial size reduction takes place. It then passes through a magnetic separator, a classifier, a chemical treater (patent pending), and it is then further reduced (by a secondary shredder) to a fine particle size. The exact particle size can be varied to meet specific firing requirements (direct firing, slurrying in oil, pyrolysis).

Pyrolysis is an exothermic process which heats organic materials to a high temperature [500-1100°C (932-2012°F)] without oxygen, resulting in the breakdown of these materials into their various components. At these high temperatures, in the absence of oxygen, most organic materials break down into three product types: a gas, a liquid (oil), and a solid (char). The pyrolytic oil produced is a chemically complex organic fluid with a sulfur content (0.1-0.3%) lower than even the best residual oils. Pyrolytic oil can be blended with no. 6 fuel oil and successfully burned in a utility boiler with properly designed fuel handling and atomizing systems. Pyrolysis is becoming increasingly popular due to its ability to convert solid waste into a fuel product with minimum environmental impact. Table 2 provides an insight into the current state-of-the-art.

A typical larger scale process (fig. 1) is that of the Tech-Air Corporation, Atlanta, GA. This pyrolytic process, initially developed at the Engineering Experiment Station at Georgia Tech, is designed to convert solid waste into charcoal (char), oil, and combustible gas. A brief description of the process follows:

Table 2. Pyrolysis processes

DEVELOPER	PRODUCTS	BTU CONTENT	TYPE	PILOT PLANT SIZE	COMMERCIAL SIZE PLANT
TECH AIR	LIQUID SOLID	12,000 LB 12,000 LB	VERTICAL SHAFT –	2 TPD & 25 TPD –	168 TPD –
MONSANTO LANDGARD	FUEL GAS SOLID	120 SCF 2500 LB	ROTARY KILN –	35 TPD –	1000 TPD –
UNION CARBIDE PUROX	FUEL GAS	300 SCF	VERTICAL SHAFT OXYGEN FED	200 TPD	–
CARBORUNDUM (ANDCO-TORRAX)	FUEL GAS	186 SCF	VERTICAL SHAFT	75 TPD	200 TPD PLANT IN EUROPE
BATTELLE	FUEL GAS	–	HORIZONTAL SHAFT (MOLTEN SALT)	2 TPD	–
MIDLAND-ROSS	FUEL GAS	–	VERTICAL SHAFT, ROTARY KILN	–	48 TPD
PYROLYTIC SYS, INC.	FUEL GAS	406 SCF	HORIZONTAL SHAFT	50 TPD	300 TPD
DEVCO MGT, INC.	FUEL GAS SOLID	– –	ROTARY KILN –	50 TPD –	1500 TPD –
POLLUTION CONTROL, LTD, DENMARK	–	–	–	5 TPD	–
URBAN R&D CORP	FUEL GAS	150 SCF	VERTICAL SHAFT	120 TPD	–

Table 2. (Continued)

DEVELOPER	PRODUCTS	BTU CONTENT	TYPE	PILOT PLANT SIZE	COMMERCIAL SIZE PLANT
WALLACE ATKINS	SOLID	3000 LB	VERTICAL SHAFT	3 TPD	50 TPD
	LIQUID	16,000 LB	–	–	–
	FUEL GAS	500 SCF	–	–	–
WEST VA UNIV	FUEL GAS	450 SCF	FLUIDIZED BED	LABORATORY	–
RUST	FUEL GAS	450 SCF	ROTARY KILN	–	260 TPD
KEMP	SOLID	–	HORIZONTAL SHAFT	5 TPD	–
	LIQUID	–	–	–	–
	FUEL GAS	–	–	–	–
BARBER-COLMAN (MICH TECH UNIV)	FUEL GAS	500 SCF	HORIZONTAL SHAFT (MOLTEN LEAD)	1 TPD	–
PAN AM RES	–	–	ROTARY KILN	LABORATORY	–
COORS	FUEL GAS	150 SCF	FLUIDIZED BED	1 TPD	24 TPD
A.D. LITTLE	FUEL GAS	–	FLUIDIZED BED	LABORATORY	–
BUR MINES	FUEL GAS	500 SCF	VERTICAL SHAFT	LABORATORY	–
KELLY COMPANY	STEAM	–	STARVED AIR INCIN	–	14 TPD
OCCIDENTAL	LIQUID	10,500 LB	VERTICAL SHAFT	4 TPD	200 TPD (100 TPD ORGANICS)

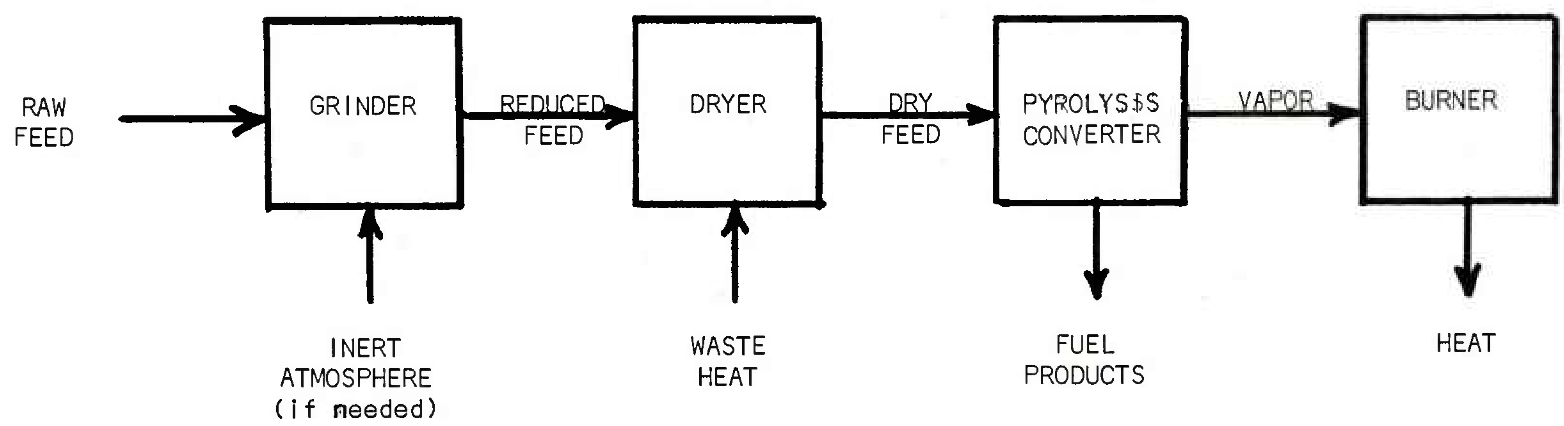

Figure 1. Typical pyrolysis process.

The waste is reduced in size by grinding and stored. When it is ready for processing, it is sent through the dryer which reduces the moisture to less than 10%. The dried feed is then conveyed to a surge bin. From the bin it is conveyed to the pyrolytic chamber where the material is thermally decomposed into charcoal (char) and oil/gas vapors. The char is removed through the bottom of the chamber, conveyed through a water spray, and discharged. The oil/gas vapors flow upward through the bed of solid waste and exit through an opening in the top of the chamber. The vapors pass through a gas cleaner, which removes entrained particles, a condenser, a demister to coalesce the oil mist to liquid, and finally through the induced draft fan to a gas burner. Approximately 50% of the gas produced will be used to dry feedstock. The "pyro-oil" generated from this process can be blended with no. 6 fuel oil. For a feed rate of 7 tph (bone dry) the output of the system is: char - 1586 kg/hr (3,500 lb/hr), oil (maximum) - 1427 kg/hr (3,150 lb/hr), and gas (above drying requirement) - 2193 kg/hr (4,841 lb/hr).

Processing Hazards

Feed Preparation

The preparation of AAP waste for use as fuel feedstock is a very energy intensive and hazardous process which consists of the following phases:

Composition. Due to the various manufacturing processes at the individual plants, arsenals, and depots, the specific makeup of the solid waste generated at each location is different. However, the waste from each site consists of the following types:

1. Non-contaminated - Similar to municipal solid waste except for a higher percentage of organic materials; primarily paper and cardboard.

2. Contaminated - Material that has been in contact with either propellants, explosives, or process chemicals. This waste is primarily cellulosic and comes from either packaging materials used for shipment or handling of explosives or discarded building materials from explosive manufacturing buildings. The waste is typically lumber, gloves, rags, and shipping boxes. Contaminated waste production is a function of the explosive production rate and the level or degree of modernization.

3. Propellant and Explosive (P&E) - Process scrap, out-dated lots, and non-specification material. These wastes are recognized as sensitive materials and precautions are taken to

protect against ignition by any source during their handling and storage. The minimum ignition energy of sensitive explosives can be as low as 0.001 mJ. Stringent precautions are necessary to avoid the accumulation of static electricity in their presence. This is normally achieved by the correct grounding of plant equipment and personnel and the use of conducting materials to prevent the retention of an electrostatic charge. A compilation of propellant and explosive sensitivity data is presented in the appendix.

Storage. To prevent boiler shutdown due to delivery truck breakdowns or days of non-production, a storage facility must be available to provide a continuous feed supply. For non-contaminated waste, this does not present a problem since a standard storage silo with bucket loaders and conveyors is suitable for use. However, contaminated and P&E waste cannot be handled so easily. Due to the possibility of sparks forming, the bucket loader approach may not be feasible with its metal-to-metal contact and the possibility of explosive dust contacting hot engine parts. A modified loader with a non-sparking blade and a pressurized enclosed engine compartment may be suitable for use. If this is not feasible, these wastes have to be stored in containerized dumpsters until required for processing.

Magnetic Separation. This operation is required to prevent stray iron from entering into the other processing steps and, in the case of explosive waste, to further prevent sparks during grinding. There should be no processing hazard associated with this operation.

Grinding. Due to the various types of wastes, each is ground differently:

1. Non-contaminated - This waste can be processed in the standard hammer mill used for municipal solid waste.

2. Contaminated - This waste presents a problem due to the presence of small amounts of propellant and explosive waste materials (usually less than 1% by weight). The difficulty in dry grinding this material occurs in the dangerous combination of combustible materials (including explosives), an oxidizing agent, and a spark. Attempts should be made to eliminate one or more of these ingredients in order to minimize the possibility of explosion. It is obviously desirable to provide some means of removing stray iron from the waste material before grinding. This is usually accomplished by either magnetic separation and/or screening. It is also of paramount importance to electrically ground the system with great care to prevent the accumulation of static electricity. When explosive

contaminated materials are ground, the hazard can be diminished by reducing the concentration of oxidizing agents in the grinding atmosphere. This can be accomplished by using an inert gas blanket or, more economically, cooled-down boiler flue gases. Naturally, explosion-proof motors and lights and non-sparking mill surfaces are among the measures available which further reduce grinding hazards.

Shock sensitivity or ease of detonation is another factor to be considered in grinding explosive contaminated material. In contrast to the relatively slow chemical changes that characterize the usual decomposition or oxidation reactions, exceedingly rapid chemical reactions may be initiated in explosive systems. The term "detonation" applies to processes in which an exothermic reaction takes place resulting in a high-pressure wave that advances with supersonic velocity (for gases, 2000 to 3000 m/sec, and for liquids and solids 3000 to 8000 m/sec) through the unreacted material. In contrast, deflagration waves travel at less than sonic velocity. Detonations are extremely damaging because of the accompanying high pressure. Consequently, an appreciation of the tendency of explosive materials and the associated initiating mechanisms to undergo these violent reactions is extremely important if disastrous incidents are to be avoided.

Primary explosives (e.g., TNT and Composition B) are placed in a separate class because of their extreme tendency to go from deflagration to detonation. There is a rather widespread tendency to neglect the shock waves produced by quick-acting solenoids, gear pumps, cavitating impellers, and the "water hammer" effect in liquid-filled lines. These can result in shocks of sufficient magnitude to initiate deflagration, as well as low- or high-order detonation, or they can at least produce incipient reactions leading to one of these catastrophic reactions. In the case of solids, impact, friction, or electric sparks may initiate a deflagration reaction which, in the more sensitive systems, may undergo a transition to detonation before the pressure is dissipated.

However, it is not enough to consider only those incidents that are likely to occur and to seek reassurance by assuming the absence of strong initiating shocks. It is essential to assess the true explosive potential of the system and to assume that the conditions for the initiation of a reaction leading to a catastrophic explosion may occur if suitable precautions are not taken. Several methods are available for evaluating energy potential: the tendency to decompose under thermal shock, the decomposition temperature, and other important factors, i.e., critical depth. These factors should not be neglected in determining the stability of materials that may be hazardous under varying conditions of manufacture, storage, or use.

The dry grinding of contaminated waste involves the hazards of high-rate shear, impingment, dust formation, and impact (fig. 2). Some of these problems can be solved by the design of the seals used on the hammer mill. A water flush on the seals has been used successfully in the past. Ignition of dust clouds containing both explosive and non-explosive materials must be prevented. Some possible solutions to this problem are (1) preventing the formation of a dust and air mixture by using a nitrogen blanket, for example, and (2) releasing pressure in case of an explosion through explosion-relief vents (vented outside) designed to prevent the equipment from rupturing. The dust problem can be minimized by the use of correctly designed dust collection equipment and good housekeeping at the end of each shift. Safety can further be enhanced with blow-out panels in the grinder (and dust collector), a water deluge system, a contained grinding room, cut-off apparatus to other process steps, and explosion-proof motor and controls.

A possible alternative to dry grinding is the Black and Clawson Hydrapulping® system. In this system, size reduction and materials handling is done hydraulically by water transport eliminating many of the problems. The potential problems in this process are the possible buildup of explosive particles in the reused water and the requirement for drying (which produces dust) prior to combustion or pyrolysis. These problems can be avoided by the use of filters and settling ponds for the process water and the selection of a thermal conversion process capable of handling organic waste with 50% moisture.

If a dryer is used, care must be taken in its design and use. Drying equipment comes in a variety of types which differ sharply in both operation and possible hazards. Those which possess moving parts are subject to the usual difficulties found around moving machinery. This is further complicated by the presence of explosives which requires specially designed seals and surfaces to reduce the probability of friction and impingement. When the material being dried becomes dusty, it is advisable to provide instrumentation to detect excessive temperatures and pressures, thereby preventing overheating that could result in a fire or explosion. Spray dryers are subject to the possibility of dust explosions typically encountered when combustible materials are handled in an atmosphere containing oxygen. Due to their rapid application of heat, flash dryers should be avoided. Hazards can be reduced by using recycled flue gases rather than straight air as the drying medium.

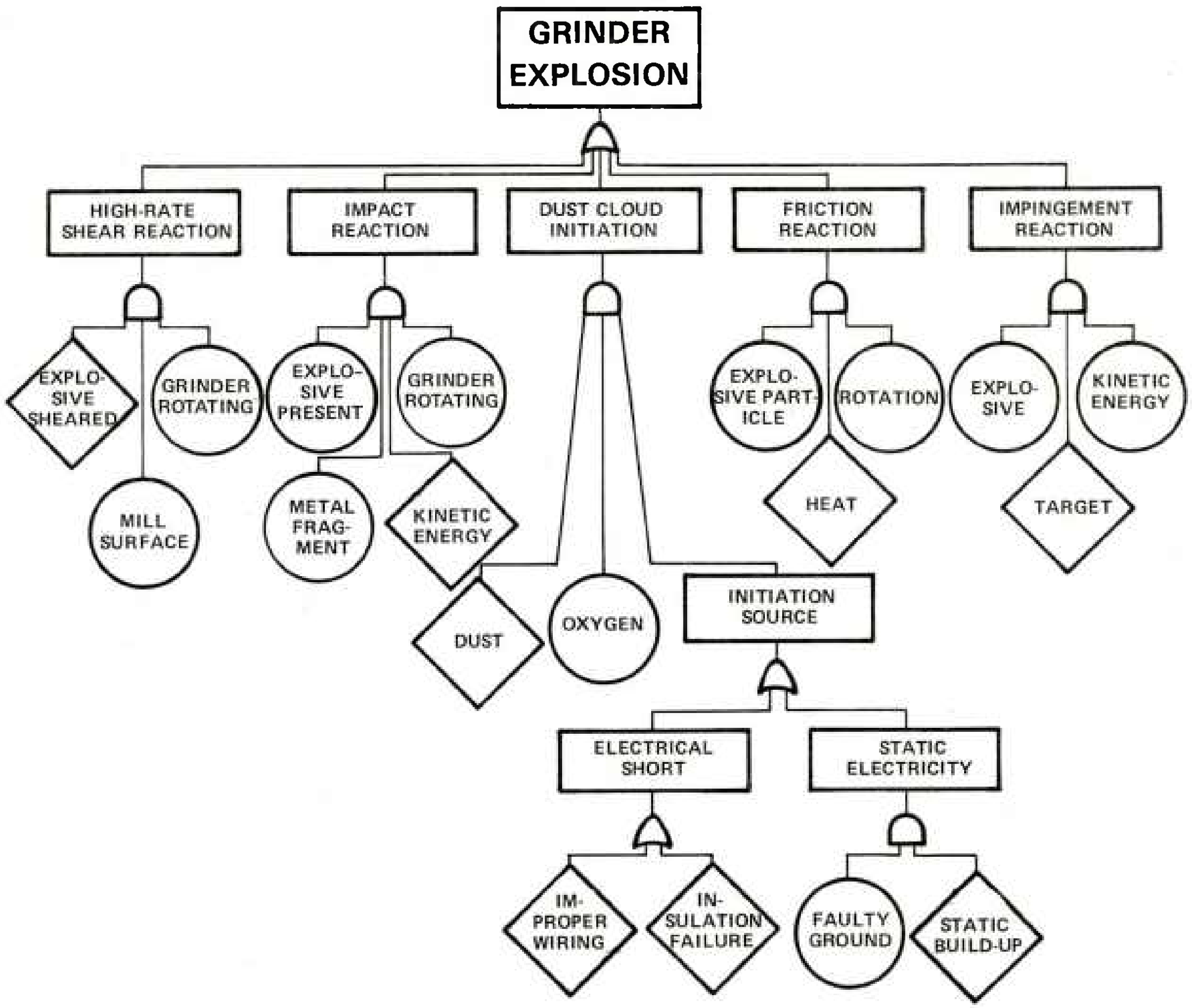

Figure 2. Fault tree analysis of grinding process.

Propellant and Explosive (P&E) Waste. P&E waste has been ground for years in a rotary knife grinder with a water overlay. The water overlay keeps the grinding area cool and prevents the P&E waste from heating up. It also reduces the possibility of sparks forming. Due to the grinder design a relatively small amount of P&E waste is in the grinder during processing. Although the normal grinder action can create localized initiation sources, such as high-rate shear, impact, friction and impingement of waste on steel, sensitivity data show that a sustained burning reaction is not expected with a 10:1 water/explosive ratio. If the P&E waste is appropriately sized (approximately 1.27 cm) and large amounts of contaminated waste are available, the P&E waste can be dispersed within the contaminated waste, avoiding the necessity of performing this operation under water.

Refuse Derived Fuel

The fundamental question concerning the safe use of RDF is "Can this type of waste be used in direct combustion applications if the power plant is in inhabited areas?" Direct combustion of propellant and explosive waste has been demonstrated by several types of incinerators (fluidized bed, rotary kiln, etc.) to be safe and ecologically sound (ref. 2). As long as the explosive particles are not too large (typically less than 1.27 cm), below the critical depth (height), and the chamber is sized to accommodate a possible detonation (with appropriate safeguards), no problems should occur. Small particles of explosive materials tend to decompose and burn rather than detonate.

Also included in the RDF category is the material obtained from the Hydrapulper. This process grinds waste and separates organics from glass and metals under water, yielding a more homogeneous blend. The conventional method of dewatering is by screws and presses. Therefore, an evaluation would have to be made as to the probability of impingement and friction causing detonation. However, due to the high water content of the material, the probability of detonation should be very low. The contamination of the metal and glass waste would dictate that it be heated for decontamination prior to discharge from the system. The process water is also contaminated with extremely small quantities of explosives and may require special explosion-proof features on pumps and other process hardware. The explosive class of the RDF will determine its use in currently existing powerhouses.

Pyrolysis

The pyrolysis of explosive contaminated waste has been conducted on a laboratory scale by the Engineering Experiment Station, Georgia Institute of Technology (ref. 3). The test program demonstrated that waste containing up to 2% (by weight) TNT can be safely pyrolyzed to produce liquid fuel. Contaminated waste has a heat content of 15.7 MJ/kg (7,000 BTU/lb) which is lost when open burned or incinerated. The process parameters (temperature, pressure, and the absence of oxygen) in the pyrolytic chamber are such that TNT completely decomposes without creating an explosive condition. The major consideration with this system is assuring that the feed is handled correctly. The standard practice of using blow-out doors (or panels) and explosion proof fixtures, and of monitoring pressure and temperature is mandated. The results of this study indicate that AAP waste can be safely pyrolyzed, with no adverse environmental impact, to produce a storable fuel having a heat content of 31.3 MJ/kg (14,000 BTU/lb).

CONCLUSIONS

The hazards analysis of the two proposed energy recovery systems and the results of the Georgia Tech experiments indicate that there are no major hazards which preclude the recovery of energy from AAP waste.

RECOMMENDATION

It is recommended that energy recovery from solid waste be investigated at all Army Ammunition Plants. At those installations where the solid waste is not sufficient to support a plant, consideration should be given to using other types of solid waste (i.e., biomass) to supplement the feedstock.

REFERENCES

1. R. G. Zalosh, "Explosion Protection in Refuse Shredding," Factory Mutual Research Corporation, December 1976.

2. R. Scola and J. S. Santos, "Fluidized Bed Incinerator for Disposal of Propellants and Explosives," Technical Report ARLCD-TR-78032, ARRADCOM, Dover, NJ October 1978.

3. J. A. Knight, L. W. Elston, and R. Scola, "Laboratory Study of Pyrolysis of Explosive Contaminated Waste," Contractor Report ARLCD-CR-78027, ARRADCOM, Dover, NJ, February 1979.

BIBLIOGRAPHY

1. D. E. Rolison, R. L. Dickerson, and R. Scola, "Evaluation of an Incinerator for Waste Propellants and Explosives," Technical Report 4984, Picatinny Arsenal, Dover, NJ

2. Norman J. Weinstein, Municipal-Scale Thermal Processing of Solid Waste, US EPA Office of Solid Waste, Washington, DC, 1977.

3. Douglas M. Considine, Energy Technology Handbook, McGraw-Hill, 1977.

4. Frederick R. Jackson, Energy From Solid Waste, Noyes Data Corporation, 1974.

5. Joseph L. Pavoni, et al, Handbook of Solid Waste Disposal, Van Nostrand Reinhold Company, 1975.

6. Paul N. Cheremisinoff and Angelo C. Morresi, Energy From Solid Waste, Marcel Dekker, Inc, 1976.

7. Philip W. Power, How to Dispose of Toxic Substances and Industrial Wastes, Noyes Data Corporation, 1976.

8. Fred N. Rubel, Incineration of Solid Wastes, Noyes Data Corporation, 1974.

9. W. Handly, Industrial Safety Handbook, McGraw-Hill, London, 1969.

10. H. Fawcett and W. Wood, Safety and Accident Prevention in Chemical Operations, John Wiley & Sons, New York, 1965.

11. H. W. Heinrich, Industrial Accident Prevention, McGraw-Hill, New York, 1950.

12. National Fire Protection Association, Report of Important Dust Explosions, Boston, Mass., 1957.

13. George Petino, et al, "Detonation Propagation Tests on Aqueous Slurries of RDX, HMX, M-1, and Nitrocellulose," Contractor Report ARLCD-CR-77002, ARRADCOM, Dover, NJ, April 1977.

14. George Petino, et al, "Detonation Propagation Tests on Aqeuous Slurries of TNT, Composition B, M-9, and M-10, Technical Report 4584, Picatinny Arsenal, Dover, NJ, November 1973.

15. R. F. Tobias, J. D. Pinkerton, and R. Scola, "Study of Energy Recovery From AAP Waste By Pyrolysis," Contractor Report ARLCD-CR-78030, ARRADCOM, Dover, NJ, March 1979.

APPENDIX A

PROPELLANT AND EXPLOSIVE SENSITIVITY DATA

Concern for the hazards in using AAP waste as a fuel source focuses on the potential for explosions in the various types of conversion processes and also in storage and handling. This concern is justified by the presence, although small, of sufficient quantities of explosive material to cause a detonation.

Damage from detonation of commercial and military explosives has been investigated and documented by many organizations. Blast damage can be related to overpressure and shock wave impulses. These factors can be related to explosive type, quantity, and mode of initiation. Knowledge of these factors can allow the prediction of system damage from the detonation of explosive materials. The potential severity of an explosive reaction can be predicted on the basis of:

1. Quantity of explosive material.

2. Type of explosive material.

3. Dispersion of material - maximum quantity of pure explosive in any one location and separation between locations of pure explosive quantities.

4. Reaction of the explosive to initiation stimulus present - friction, impact, spark, and heat.

5. Transition characteristics of the explosive.

6. Confinement of the explosive.

7. Structural integrity of the equipment.

8. Safety modifications to equipment (i.e., blow-out panels).

The factors that govern the probability of an explosion in a piece of equipment are the presence of both explosive material and an initiation source. The exact quantity of explosive present will have to be determined by a study of the typical explosive contamination of the solid waste at a particular plant. The various initiation modes will have to be evaluated for each candidate conversion system.

A series of tables[1] listing sensitivity data for a series of explosive materials is presented for the reader's convenience. The type of data presented in the individual tables is as follows:

Table 1 - The maximum impact, friction, or ESD energies applied to propellant or explosive materials tested which did not result in an initiation in 20 consecutive trials. At least one sample initiation occurred at a higher test level or as otherwise specified.

Table 2 - The maximum propelled impingement energies applied to propellant or explosive materials tested which did not result in an initiation in any of ten consecutive trials. At least one sample initiation occurred at a higher test level or as otherwise specified.

Table 3 - The minimum dust-to-air concentrations for explosive reactions, the minimum ESD spark energy required to initiate an explosive dust/air mixture, and the maximum thickness of a propellant or explosive tested which did not propagate an explosive reaction.

Table 4 - a. The maximum (critical) diameter of a propellant or explosive material tested in a particular confinement (or unconfined) which will not propagate an explosive reaction.

b. The critical height of a propellant or explosive material tested in steel pipe or other confinement which will not transit from flame initiation to an explosive reaction.

[1]Ewing, T. W. and Cabbage, W. A., "A Compilation of Hazards Test Data for Propellants and Related Materials," PE-489, Radford Army Ammunition Plant, September 1976.

Table A-1. Impact/friction/electrostatic discharge

Material	Physical condition	Thickness (mm)	Impact (J/m^2)	Friction (GN/m^2 at m/sec)	ESD (joules)
M7	Fines, water wet	2.0	$2.4x10^4$	0.75/3.0	1.76
M26	Fines, dry	0.76	$1.4x10^4$	0.59/1.8	0.26
N-5	Paste,. dry	0.84	$1.8x10^4$	0.22/2.4	0.075
XM-33	Paste, water wet	0.076	$2.7x10^4$	0.5/2.4	0.075
M-30	Paste, solvent wet	0.86	$0.72x10^4$	0.33/2.4	--
	process fines	0.8	$2.2x10^4$	0.5/3.0	0.26
Comp B	Solid, fines	0.84	$2.8x10^4$	0.4/2.4	0.024
RDX "E"	Solid, dry	0.84	$3.4x10^4$	0.26/2.4	0.024
TNT	Dust, fines, dry	0.13	$6.7x10^4$	1.3/0.6	0.013
NC	Linters, dry	0.15	$0.46x10^4$	0.16/2.4	0.049

Notes:

1. Impact Test - This test determines the maximum impact energy which will not ignite propellant or explosive materials. The material being tested is exposed to the impact energy of a falling weight. The falling-weight drop height and/or intermediate hammer materials are varied to simulate impact conditions. In this data compilation, the anvil and intermediate hammer materials are steel unless otherwise noted. The impact energy is measured and expressed as joules per square meter or contact area between the impacting surfaces for solids. Initiation of the sample under test is determined by the detection of gaseous combustion products using infrared absorption or an ionization chamber, or by the presence of odor, flash, and/or noise.

2. Friction Test - This test determines the maximum frictional energy which will not ignite propellant or explosive materials. The material being tested is exposed to the friction generated between a stationary wheel and a sliding anvil surface. The pressure of the wheel upon the anvil, the speed of the anvil, and the wheel and anvil materials are varied to simulate in-process frictional forces. In

Table A-1. (Continued)

this data compilation, the wheel and anvil materials are steel unless otherwise noted. The friction generated is expressed as newtons per square meter of contact area between the wheel and anvil at the anvil speed used for the test. Initiation of the sample is determined by the detection of gaseous combustion products using infrared absorption, an ionization chamber or by the presence of odor, flash and/or noise.

3. Electrostatic Discharge (ESD) Sensitivity Test - This test determines the minimum electrostatic discharge energy which will ignite propellant or explosive samples. Electrostatic energy stored in a charged capacitor is discharged through the propellant or explosive during testing. The energy discharged is measured in volts and recorded in joules.

Table A-2. Impingement

Material	Physical condition	Granule size, (mm)	Target angle (degrees)	Propelled impingement (m/sec)
M26 (106 mm)	Granule	13.0Lx5.6D	45	28.5
M30 (76 mm)	Granule	20.0Lx8.2D	90	$\geqslant$ 63.0
Solvent/NC	Slurry, 40/60	N/A	90	73.2
Comp B	Cylindrical	16Lx16D	90	172
RDX	Dry	--	90	207
TNT	Cylindrical	16Lx16D	90	168

Table A-3. Dust explosibility (air)

Material	Physical condition	Particle size (microns)	Minimum conc (g/m^3)	Minimum energy (joules)
M1	Fines, dry	149	1500	0.162
M26	Fines, dry	< 88	40	0.12
M30	Fines, dry	< 88	60	0.31
TNT	Dry	<840	70	0.075
HMX	Fines, dry	< 53	470	0.02
NC	Fines, dry	< 53	850	$\geq$5.0

Note:

Dust Explosibility Test

The objectives of this test are to determine (1) minimum explosive concentration for explosive dusts dispersed in air and (2) minimum electrostatic discharge energy required to ignite an explosive dust dispersed in air. Both tests are accomplished using the Bureau of Mines Hartmann Dust Explosibility Test Apparatus.

(1) Explosive Dust/Air Concentrations

Various amounts of a finely divided solid are dispersed in a constant volume of air and exposed to a glowing tungsten probe heated by 60 hertz, AC high voltage electrical discharges. An explosive dust/air mixture is that quantity of dust required to generate sufficient pressure upon initiation within the combustion tube to rupture a filter-paper diaphragm at one end of the tube. The minumum explosive dust/air composition is recorded in grams of dust dispersed in one cubic meter of air.

(2) Minimum Electrostatic Discharge Energy

In this test a dust/air mixture in the explosive range is exposed to various condenser discharge spark initiation energies. The minimum electrostatic discharge energy is defined as the lowest energy which will ignite the dust/air mixture and result in a flash extending a minimum of four inches above the ignition point (the paper-filter diaphragm may or may not be ruptured). The minimum initiation energy is recorded in joules.

Table A-4. Critical diameter/height

Material	Physical condition	Dimensions (mm)	Bulk density (g/cm^3)	Critical diameter (cm)	Diameter pipe (cm)	Critical height (cm)
M1	Lumpy, 35% Solvent wet	NA	0.43	3.8	5.1	>122
M26 (106 mm)	Granules	13.1x6.76	0.62	2.5	2.5	>117
N5	Fines, dry	NA	0.10	<5.1	10.2	> 61
M30 (105 mm)	Granules	19.9x8.28	0.74	<2.5	2.5	> 91 < 99
TNT	Flake	0.6 x variable	0.833	2.5 unconfined	2.5	23
NC	Dry			<.64 unconfined	2.5	2.5
Comp B	Fines	74μ	NA		5.1	

Notes:

1. Critical Diameter Test - The propellant or explosive (acceptor material) is subjected to pressures of a detonating high-energy donor to determine the minimum dimension required to induce a sustaining explosive reaction in the acceptor material. Testing is conducted using various diameters of solid propellant samples and confinement. The acceptor test sample length is maintained to a minimum of four times its diameter. The explosive donor (Composition C-4) diameter is equal to that of the test specimen and has a minimum length equal to three times its diameter plus one inch for the initiating cap. The explosive donor is initiated by a J-2 blasting cap.

Table A-4 (Continued)

Critical diameter data are reported as the largest sample dimension which showed no evidence of propagating an explosive reaction through the test specimen. Test information is used to assess explosive propagation potentials of propellant and explosive configurations encountered during process situations.

2. Critical Height-to-Explosion Test - The propellant or explosive is subjected to submerged flame initiation to determine if the material reacts explosively in varying degrees of confinement. Testing is generally conducted using Schedule 40 black, seamless steel pipe open at one end. Test variables include the pipe length and diameter and material height within the pipe. Flame initiation is provided by a 12-gram bag igniter consisting of a 50/50 mixture of FFFG black powder and 2056D casting powder, and a M100 Atlas Match.

Critical height-to-explosion data are reported as the greatest material height tested in a given container diameter which did not result in transition from burning to an explosive reaction during any of three or more trials at that level. In this compilation, submerged flame initiation data are assumed unless otherwise noted.

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